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Lake Hefner
Oklahoma County, Oklahoma

National Eutrophication Survey, Corvallis, Oreg

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NATIONAL EUTROPHICATION SURVEY
WORKING PAPER SERIES

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REPORT

ON

LAKE HEFNER

OKLAHOMA COUNTY

OKLAHOMA

EPA REGION VI

WORKING PAPER No. 500

WITH THE COOPERATION OF THE

OKLAHOMA DEPARTMENT OF POLLUTION CONTROL

AND THE

OKLAHOMA NATIONAL GUARD

MARCH, 1977

TECHNICAL REPORT DATA

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16. ABSTRACT:

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT ON LAKE HEFNER

OKLAHOMA COUNTY, OKLAHOMA

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 590

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Oklahoma Department of Pollution Control for professional involvement, to the Oklahoma National Guard for conducting the tributary sampling phase of the Survey, and to those Oklahoma wastewater treatment plant operators who provided effluent samples and flow data.

Dr. Denver Talley, Director, Oklahoma Department of Pollution Control; the staff of the Oklahoma Water Resources Board; and the staff of the Oklahoma State Department of Health reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper Series.

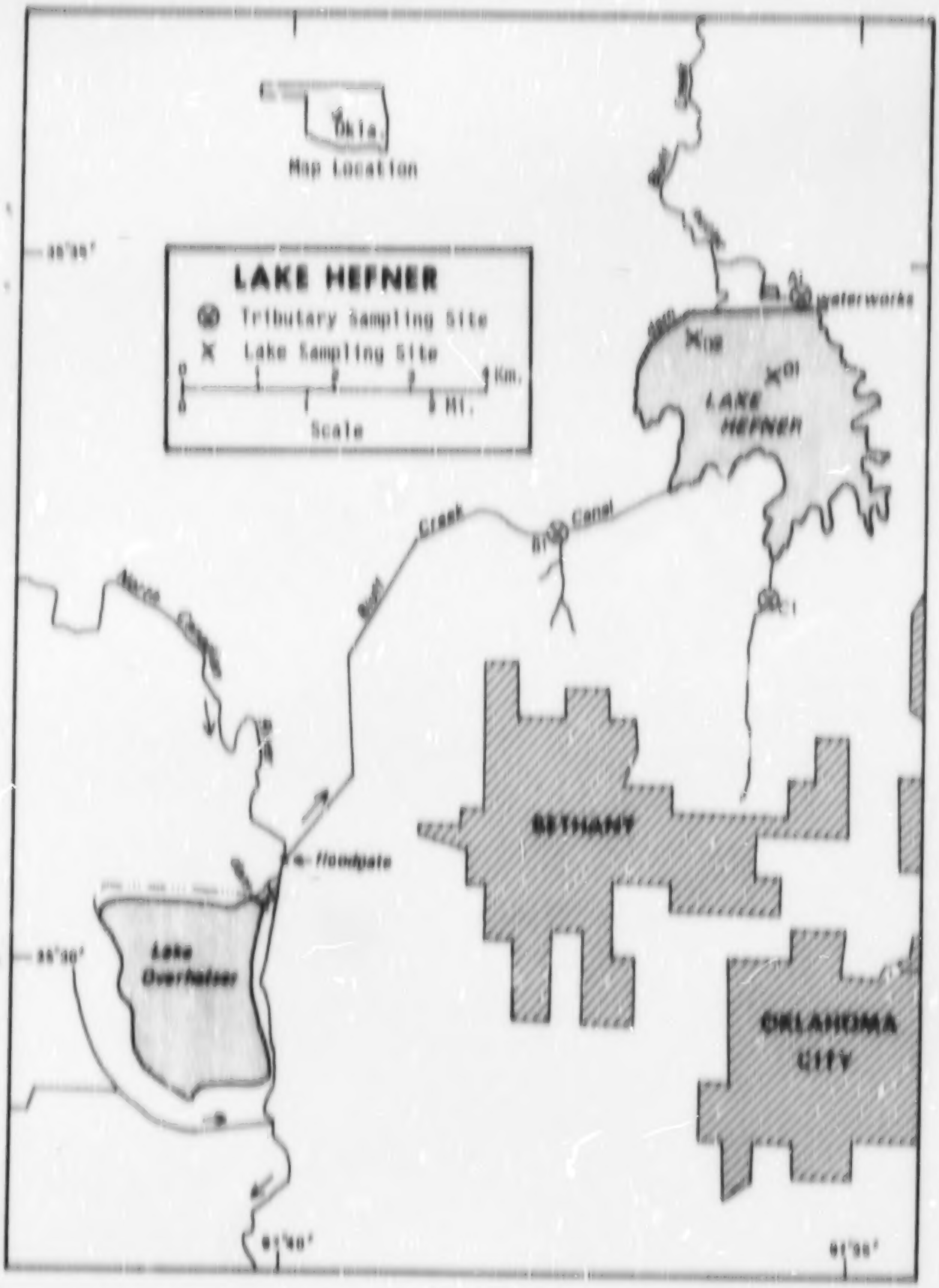
Major General John Coffey, Jr., the Adjutant General of Oklahoma, and Project Officers Colonel Curtis W. Milligan and Major James O. Haney, Jr., who directed the volunteer efforts of the Oklahoma National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF OKLAHOMA

LAKE NAME	COUNTY
Altus Reservoir	Greer, Kiowa
Arbuckle Lake	Murray
Lake Ellsworth	Caddo, Comanche
Lake Eufaula	Haskell, McIntosh, Okmulgee, Pittsburg
Fort Cobb Reservoir	Caddo
Fort Supply Reservoir	Woodward
Foss Dam Reservoir	Custer
Lake Frances	Adair
Grand Lake O' The Cherokees	Mayes, Delaware, Craig, Ottowa
Lake Hefner	Oklahoma
Keystone Reservoir	Tulsa, Creek, Osage, Pawnee
Oologah Lake	Nowata, Rogers
Tenkiller Ferry Reservoir	Cherokee, Sequoyah
Lake Thunderbird	Cleveland
Wister Reservoir	Leflore


Okla.
Map Location
LAKE HEFNER
Tributary Sampling Site
Lake Sampling Site
Km.
Mi.
Scale
waterworks
LAKE HEFNER
Canal
Creek
Floodgate
Lake Overholser
BETHANY
OKLAHOMA CITY
35°30'
97°40'
97°35'

REPORT ON LAKE HEFNER, OKLAHOMA
STORET NO. 4010

I. CONCLUSIONS

A. Trophic Condition:*

On the basis of field observations and Survey data, Lake Hefner is considered eutrophic, i.e., nutrient rich and highly productive. Whether such nutrient enrichment is to be considered beneficial or deleterious is determined by its actual or potential impact upon designated beneficial water uses of each lake.

Potential for primary production as indicated by algal assay control yield was high on both sampling occasions. Chlorophyll *a* values in the lake ranged from 0.9 µg/l to 8.6 µg/l with a mean of 5.7 µg/l. Of the 16 Oklahoma lakes, (including Lake Texoma) sampled in 1974, 7 had higher median total phosphorus levels, 6 had higher median inorganic nitrogen values, and 3 had higher median orthophosphorus levels than Lake Hefner.

Survey limnologists did not report any problem algal blooms or macrophyte growths in the lake. However, low Secchi disc readings (range of 0.8 to 1.2 m) suggest that light may be limiting primary production in Lake Hefner.

*See Appendix E.

B. Rate-Limiting Nutrients:

Algal assay data indicate phosphorus was the primary limiting nutrient in Lake Hefner during spring sampling and nitrogen was limiting during fall. Mean inorganic nitrogen to orthophosphorus (N/P) ratios in the lake data were 8/1 or less on all sampling occasions, indicating primary limitation by nitrogen.

C. Nutrient Controllability:

1. Point sources -

There were two municipal point sources (El Reno and Yukon) known to impact Lake Hefner during the 1974 sampling year. However, loadings from these plants are not defined in the lake nutrient budget on pages 13 and 14. Lake Hefner is a storage reservoir for Oklahoma City and water is pumped in from the North Canadian River (through Bluff Creek Canal) when its flow is sufficient for pumping. Input from the sewage treatment plants is indirectly received to Lake Hefner via this pumping, and estimations for actual annual contributions to the lake from these sources are not available. Plant loadings are reflected, however, in the calculated loadings for Bluff Creek Canal (B-1).

The estimated annual phosphorus loading to Lake Hefner of 0.45 g $P/m^2/yr$ is greater than Vollenweider's proposed "eutrophic" level (1975). Although Vollenweider's model may

not be applicable to lakes in which optimmetic light penetration is severely restricted by the presence of suspended solids, actual annual loading to the lake may be higher than calculated due to runoff from Oklahoma City or unmeasured sewage treatment plant influences. Thus, any future nutrient addition to the lake should be carefully evaluated as to its potential impact on the trophic state of the lake.

2. Nonpoint sources -

During the sampling year, nonpoint sources (including precipitation) contributed all of the calculated nutrient budget to Lake Hefner. The Bluff Creek Canal (pumping some impounded water from the North Canadian River) contributed 93.7% of the total phosphorus load, and ungaged drainage areas contributed an estimated 2.4%.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake surface area and mean depth were provided by the Oklahoma Department of Pollution Control; maximum depth was provided by the Oklahoma Water Resources Board. Tributary flow data were provided by the Oklahoma District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 10.12 km^2.
2. Mean depth: 9.1 meters.
3. Maximum depth: 26.2 meters.
4. Volume: 92,092 x 10^6 m^3.
5. Mean hydraulic retention time: 1,077 days (2.9 yrs).

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area (km^2)	Mean flow (m^3/sec)
B-1 Bluff Creek Canal*	0.0	1.48
Minor tributaries and immediate drainage -	15.0	0.04
Totals	15.0	1.52

2. Outlet - A-1 Lake Hefner Waterworks* - 25.1 0.00

C. Precipitation:

1. Year of sampling: 103.7 cm.
2. Mean annual: 87.9 cm.

*A-1 and B-1 are canals which flow according to man's needs.

III. LAKE WATER QUALITY SUMMARY

Lake Hefner was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from three stations on the lake (Station 02 and 03 were only sampled twice) and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll *a* analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 18.3 meters at Station 01, 18.6 meters at Station 02, and 4.3 meters at Station 03. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll *a* determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/29/74	1. Cyclotella	74
	2. Oocystis	55
	3. Chroomonas	18
	4. Cryptomonas	18
	5. Nitzschia	18
	Other genera	...
	Total	183
06/11/74	1. Chroomonas	507
	2. Microcystis	362
	3. Anabaena	181
	4. Oocystis	181
	5. Microcystis	72
	Other genera	219
	Total	1,522
10/24/74	1. Chroomonas	556
	2. Coelosphaerium	75
	3. Stephenodiscus	68
	4. Dactylococcopsis	31
	5. Tetrastrum	25
	Other genera	102
	Total	857

F. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/29/74	01	0.9
	02	***
	03	***
06/11/74	01	***
	02	8.6
	03	6.6
10/24/74	01	6.4
	02	5.4
	03	6.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l dry wt.)
a. 03/29/74			
Control	0.020	0.292	5.0
0.05 P	0.070	0.292	12.2
0.05 P + 1.0 N	0.070	1.292	89.1
1.00 N	0.020	1.292	5.2
b. 10/24/74			
Control	0.026	0.139	3.0
0.05 P	0.076	0.139	3.1
0.05 P + 1.0 N	0.076	1.139	20.0
1.00 N	0.026	1.139	7.3

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity was high in Lake Hefner during both spring and fall sampling. It is anticipated that the control yield would have been substantially higher were it not for significant nutrient losses occurring between the time of sample collection and assay. The nutrient loss changed the relative proportions of inorganic nitrogen to orthophosphorus resulting in assay results of questionable utility, at best.

In the spring sample, the addition of phosphorus alone produced a significant increase in yield over that of the control, indicating phosphorus limitation. The addition of nitrogen alone did not result in any increase in yield over that of the control. In the autumn assay, the addition of nitrogen alone resulted in a significant increase in yield, indicating nitrogen limitation at that time. The maximum increases in yield over that of the control were achieved with the simultaneous addition of both nutrients.

Mean N/P ratios in the lake data were 8/1 or less on all sampling occasions, suggesting primary limitation by nitrogen (a mean N/P ratio of 14/1 or greater generally reflects phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Oklahoma National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and May when generally two samples were collected. Sampling was begun in November 1974, and completed in August 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Oklahoma District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual concentrations in Unnamed Creek at Station C-1 and mean annual ZZ flow.

A. Waste Sources:

1. Known municipal -

Name	Pop.* Served	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
El Reno†	14,510	Trickling Filter	5.492**	North Canadian River
Yukon†	7,000	Stabilization pond	2.650**	North Canadian River

2. Known industrial - None

*U.S.EPA, 1971.
**Estimated at 0.3785 m^3/capita/day.
†Lake Hefner is a storage reservoir for Oklahoma City and water is pumped in from the North Canadian River when its flow is sufficient for pumping. Thus, input from sewage treatment plants is indirectly received to Lake Hefner via this pumping.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-1 Bluff Creek Canal	4,250	93.7
b. Minor tributaries and immediate drainage (nonpoint load) -	110	2.4
c. Known municipal STP's* -		
El Reno	?	
Yukon	?	
d. Septic tanks - None		
e. Known industrial - None		
f. Direct precipitation** -	175	3.9
Totals	4,535	100.0
2. Output - A-1 Lake Hefner Waterworks -	950	
3. Net annual P accumulation -	3,585	

*See footnote 1, page 12.
**Estimated (See NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-1 Bluff Creek Canal	49,025	79.8
b. Minor tributaries and immediate drainage (nonpoint load) -	1,520	2.5
c. Known municipal STP's* -		
El Reno	?	
Yukon	?	
d. Septic tanks - None		
e. Known industrial - None		
f. Direct precipitation** -	10,925	17.7
Totals	61,470	100.0
2. Output - A-1 Lake Hefner Waterworks -	54,640	
3. Net annual N accumulation -	6,830	

*See footnote 1, page 12.
**Estimated (See Working Paper No. 175).

D. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
D-1 Unnamed Creek	0.089	1.205
D-1 Chisholm Creek	0.075	6.320

f. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his "eutrophic" loading is that at which the receiving waters would become eutrophic or remain eutrophic; his "oligotrophic" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A "mesotrophic" loading would be considered one between "eutrophic" and "oligotrophic".

Note that Vollenweider's model may not be applicable to water bodies with very short retention times or in which light penetration is severely restricted from high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for Lake Hefner	0.45
Vollenweider's "eutrophic" loading	0.34
Vollenweider's "oligotrophic" loading	0.17

V. LITERATURE

U.S. Environmental Protection Agency. 1971. "Inventory of Wastewater Treatment Facilities" EPA Publication No. OWP-1, Volume 5. Office of Media Programs, Office of Water Programs, Washington, D.C.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B
TRIBUTARY FLOW DATA

APPENDIX C

PHYSICAL AND CHEMICAL DATA

APPENDIX D

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]

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DATE	TIME	DEPTH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	TO		[illegible]	%	TOTAL	[illegible]	
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APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF OKLAHOMA

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